Departement für Kleintiere, Abteilung für Bildgebende Diagnostik
der Vetsuisse-Fakultät Universität Zürich

Direktor: Prof. Dr. med. vet. Patrick R. Kircher

The Advanced Locking Plate System (ALPS)

Application and results in 71 small animal patients

Inaugural-Dissertation
zur Erlangung der Doktorwürde
der Vetsuisse-Fakultät, Universität Zürich

vorgelegt von

Nicole Scherrer

Tierärztin

von Zürich

genehmigt auf Antrag von

Prof. Dr. med. vet. Patrick R. Kircher, Referent
Prof. Dr. med. vet. Tomás Guerrero, Korreferent

CONTENTS

1 Summary

Objective – To evaluate the results of application of the advanced locking plate system (ALPS) in small animal surgery.

Study Design – Case series.

Animals – Client-owner dogs and cats (n=71) that were treated with ALPS (n= 72).

Methods – Animals treated with ALPS (2007-2010) were evaluated. Data included signalement, indication for surgery, outcome and complications.

Results – 29 dogs and 42 cats were treated. 54 bone fractures and 12 tarsal or carpal ligament-injuries were stabilized with ALPS. In 6 cases ALPS was used to prevent or treat fractures during total hip replacement surgery. Complications needing revision surgery occurred in 3 fractures and 1 carpal arthrodesis (5.5%): (1) A fracture occurred through a screw-hole in a radius/ulna fracture in a cat; (2) fixation failure occurred in a femoral fracture in a cat with all monocortical fixations of the proximal fragment being pulled out of the bone; (3) a radius/ulna fracture in a dog needed revision surgery because of non-healing and implants getting loose; and (4) the distal fixation of a carpal arthrodesis in a cat becoming loose before the arthrodesis healed. All cases went to healing by the end of the study. Main complication after tarsal arthrodesis was suture dehiscence.

Conclusions – ALPS offers a reliable alternative for treating fractures and other orthopedic conditions in small animals.

2 Introduction

Locking plate systems work as internal fixators and have some advantages compared to conventional plates: They respect biological fracture healing by minimizing damage to the blood supply [1-4], the locking mechanism between screw and plate-hole provides angular stability increasing the construct strength [4-6] and reduces implant to bone contact [3, 4, 7]. Stability does not depend on compression of the plate onto the bone as with conventional plates, and therefore periosteal blood supply remains preserved [3, 7-9]. These factors contribute to decrease the time of fracture healing and the risk of infection [1, 3]. Endosteal blood supply is preserved because screws can be inserted monocortically, and therefore bilateral or orthogonal plates can be applied with less vascular trauma [1]. The incidence of screw loosening or screw pull-out is decreased because the plate is under minimal tension [8, 10].

Internal fixators do need less exact countering to fit the bone making its handling simpler, surgery time shorter, and the possibility of loss of primary reduction decreased [3,4,8,9]. This allows performing an indirect approach to reduce the fracture rather than an open reduction with damage of the surrounding tissue. This technique is termed minimally invasive plate osteosynthesis (MIPO) [3,8]. MIPO can be used with locking plates or with conventional plates [11-13], but the ease of use of the locking systems makes them probably a better option [4,12]. Locking plate systems were originally developed for human surgery, and a main disadvantage of many of the actual systems is the price. The Advanced Locking Plate System (ALPS) is a novel locking plate system, developed exclusively for veterinary use. Until now, only one case report on a tarsal arthrodesis in a cat with two ALPS, and two studies comparing mechanical properties of ALPS plates with other implants have been published [14-16]. The aim of this retrospective study was to describe the ALPS system, to evaluate the first three years of application of ALPS at the Vetsuisse-Faculty, University of Zurich, and to describe the outcome of the patients. We hypothesized that ALPS is a suitable alternative to treat small animal-fractures, arthrodesis, and to be combined with cementless total hip replacement.

3 Material and methods

Advanced Locking Plate System (ALPS)

Plates are available in the widths of 5mm, 6,5mm, 8mm, 10mm and 11mm. The screws lock into the plate-holes by means of 2 locking mechanisms: (a) the threads of the plate hole lock with the proximal first threads of the screw. This means that the whole screw threads in the plate hole, and (b) the screw head and the plate hole have a conical shape that holds the screw in a stable position (figure 1) [1,14].

The plates are made of titanium grade 4 and the self-tapping screws are made of titanium alloy. Locking- or non-locking-screws can be inserted in each plate-hole. The locking screws need to be inserted perpendicular to the plate. Non-locking screws can be inserted in neutral function with +/- 30° longitudinal and +/- 5° transverse angulation or in compression function (figure 2). Screw sizing is designed such that the standard cortical screws may be removed and replaced in the same hole with the larger locking screw [1].

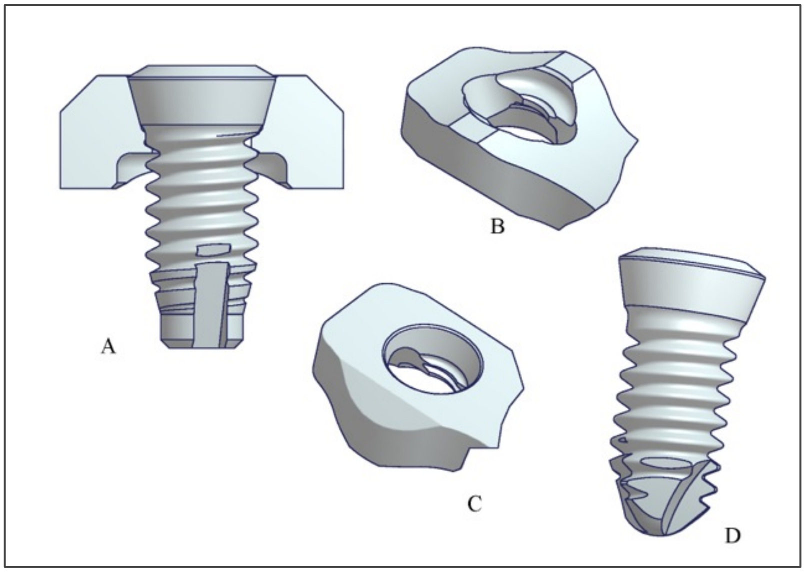


Figure 1: (A) Cross section of a plate/screw through the plate-hole showing the conical shape of the screw-head locking within the plate-hole. Partial threads in the plate-hole contribute with the locking mechanism. A first generation screw is shown. (B) Perspective view of the plate-hole from bottom and (C) top showing the partial threads and the conical shape of the plate-hole. (D) Drawing showing a second generation screw with improved cutting flutes (Figures 1-6 taken with permission from www.kyon.ch, Kyon Pharma, Inc. Zurich, Switzerland)

Figure 2: ALPS plate profile with non-locking-screws in angled position (golden screws), locking screws (green screws) and screw hole plug (blue screw). Note the conical shape of the head of the locking screws that contributes to hold the screw in an angular-stable position

The plates can be bent in both planes (figure 3). The special profile of the plate provides small contact areas to the bone to reduce compression of periosteum (figure 4).

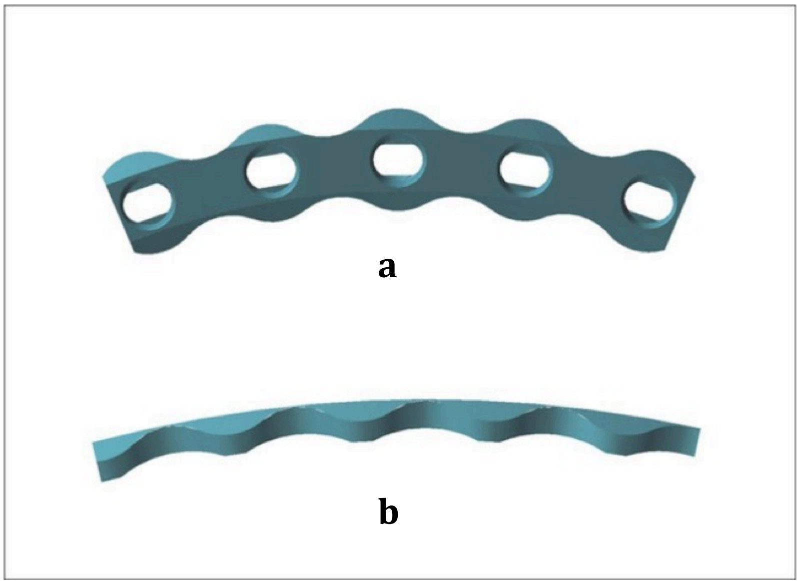


Figure 3: ALPS plate: in plane (a) and out-of-plane (b) bending

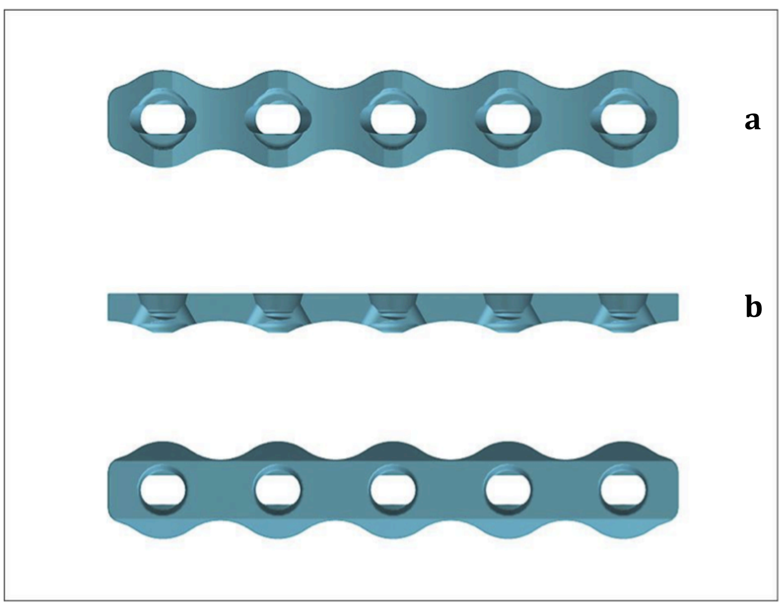


Figure 4: ALPS plates profiles: bottom view (a), side view (b) and top view (c). Note the underside profile in the lateral view that allows for small contact areas on the bone

ALPS plate	Locking screws	Non-locking screws	Plate length
5mm	2.4mm (6, 8, 10, 12, 14 and 16mm-long)	1.5mm (6, 7, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28 and 30mm-long)	Cuttable to the needed length
6.5mm	2.4mm (6, 8, 10, 12, 14 and 16mm-long)	1.5mm (6, 7, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28 and 30mm-long)	Cuttable to the needed length
8mm	3.2mm (8, 10, 12, 14, 16 and 18mm-long)	2.4mm (10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 and 32mm-long)	Cuttable to the needed length
10mm	4.0mm (10, 12, 14, 16, 18 and-20mm long)	2.7mm (10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 and 32mm-long)	2 to 12 holes
11mm	4.0mm (10, 12, 14, 16, 18 and-20mm long)	2.7mm (10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 and 32mm-long)	4 to 18 holes

Table 1: available plate sizes and compatible locking- and non-locking screws

Instruments used for the application of ALPS plates are drill bits, drill stop, drill sleeves for locking (figure 5), neutral and compression screws, depth gauge, screwdriver handle and screwdriver insert, bending iron for in-plane bending (figure 6) and bending pliers for out-of-plane bending.

Application of ALPS implies proper contouring of the plate to the bone, fixation of the proximal and distal parts of the plate to the bone using non-locking screws, and further stabilization using looking screws. Looking screws are preferentially positioned in a monocortical fashion to protect the endosteal blood supply [1].

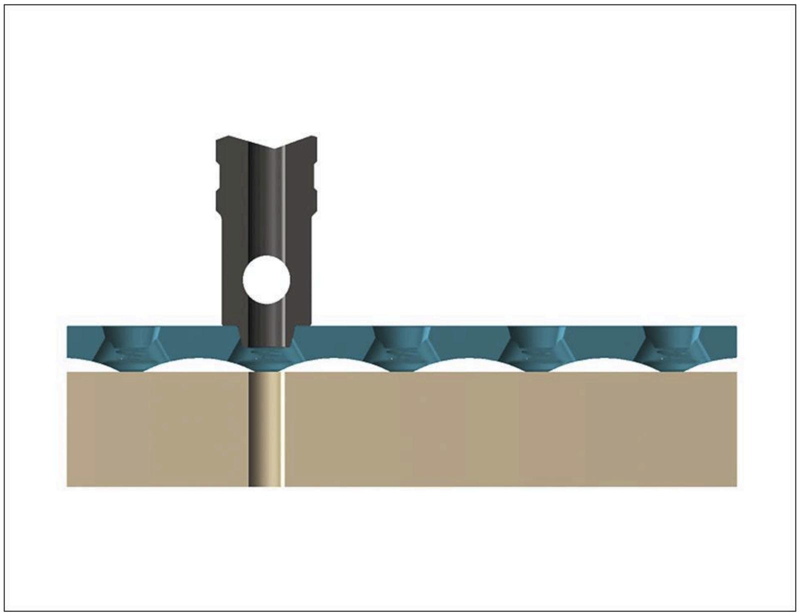


Figure 5: ALPS locking screw drill sleeve: it is held in position by pressing onto the plate

Figure 6: ALPS in plane bending pliers

Inclusion criteria

Data from all consecutive dogs and cats treated with ALPS at the Vetsuisse-Faculty, University of Zurich, between April 2007 and April 2010 were included in this study. All owners signed a consent form allowing all documentation regarding their animals to be used for scientific research and publication. Data retrieved from medical records included breed, body weight, age, gender, indication for surgery, outcome and complications. Telephone contact with owners who did not return for re-evaluation was attempted. Only those dogs and cats that had clinical and radiographic evaluation were included in this study. Indication for use of ALPS was divided in three groups: Fracture treatment, tarsal/carpal joint instability/luxation, and in combination with total hip replacement.

Anesthetic protocol:

Cats were premedicated with ketamine (Narketan®, Vétoquinol AG, Switzerland) 5 mg/kg and midazolam (Dormicum®, Roche Pharma AG, Switzerland) 0.1 mg/kg intramuscularly (IM); dogs were premedicated with methadone (Methadon®, Streuli Pharma AG, Switzerland) 0.2 mg/kg in combination with acepromazine (Prequillan®, Arovet AG, Switzerland) 0.03 mg/kg IM. Anesthesia was induced with propofol intravenously (IV) (Propofol 1% MCT Fresenius®, Fresenius Kabi, Switzerland) to effect. After endotracheal intubation, anesthesia was maintained using isoflurane (IsoFlo®, Abbott AG, Switzerland) and a constant rate infusion (CRI) of fentanyl (Sintenyl®, Sintetica S.A., Switzerland). If indicated, epidural anesthesia was performed using morphine (Morphin HCl Sintetica®, Sintetica S.A., Switzerland) 0.1 mg/kg and bupivacaine 0.5 % (Carbostesin®, Astra Zeneca, Switzerland) 0.5 mg/kg.

Cefazolin (Kefzol®, Teva Pharma AG, Switzerland) 22 mg/kg IV was administered at induction and repeated every 90 minutes during anesthesia. Intra-operative patient monitoring was performed routinely; lactated Ringer's solution was administered to all patients.

Postoperative analgesia consisted of an opioid (methadone, buprenorphine (Temgesic®, Reckitt Benckiser, Switzerland), or fentanyl) IV in combination with a non-steroidal anti-inflammatory drug (NSAID; meloxicam (Metacam®, Boehringer Ingelheim GmbH, Germany) or carprofen (Rimadyl®, Pfizer AG, Switzerland)) IV or per os.

4 Results

Eighty-four dogs and cats were treated with ALPS. Of the 84 patients, complete data with follow-up ≥ 6 weeks was retrieved from 71 animals (72 treatments) (29 dogs: 5 mix breed dogs, 1 Shetland Sheepdog, 1 Lhasa Apso, 1 Rhodesian Ridgeback, 3 Jack Russell Terrier, 1 Golden Retriever, 1 poodle, 1 Papillion, 1 Bernese Mountain Dog, 2 Appenzell Mountain Dog, 1 Entlebucher Mountain Dog, 1 Shih-Tzu, 1 Welsh Corgi Pembroke, 1 French Bulldog, 4 Labrador Retriever, 1 Beagle, 1 Miniature Pinscher, 1 Border Collie, 1 Bolonka Zwetna and 42 cats: 1 Norwegian Wood Cat, 1 Siamese Cat, 40 European Shorthair Cats). The mean age of the dogs in this study was 3.9 years (4 months to 13 years), and of the cats was 4.8 years (7 months to 13 years). The mean body weight of dogs was 19 kg (1.8 to 55 kg) and of cats was 4.5 kg (2 to 7.6 kg). Among the dogs there were 16 female and 13 male, and in the cats 16 female and 26 males were represented.

The surgeries were performed by a team consisting of various combinations of ECVS board certified surgeons and surgical residents. Twelve surgeons with different grades of expertise were involved in the procedures.

Description of stabilization method

Fractures

Fifty-four bone fractures in 53 patients were stabilized with ALPS. Affected bones were humerus (1), radius/ulna (14), metacarpal bones (2), femur (19) tibia/fibula (5), metatarsal bones (2), pelvis (9: Ilium 8, acetabulum 1), sacrum (1) and mandible (1). Data is provided in table 2.

In two fracture-cases, ALPS was used for revision surgery. Once to revise a non-healing open radius/ulna fracture treated with an external fixator, and once to revise a collapsed femoral fracture in a cat previously stabilized using external fixation. Both cases healed uneventfully.

In 4 cases of fractures in cats ALPS was combined with other implants: Twice in a plate-rod configuration to treat comminuted diaphyseal femoral fractures, and twice to stabilize serial fractures of the metabones (one metacarpal and one metatarsal). In both cases the metabones 3 and 4 were stabilized with ALPS and the metabones 2 and 5 were stabilized with IM pins.

Bone	Primary/ Revision surgery	Localization	Dog	Cat	Complications	Revision after ALPS
Humerus	Primary fracture stabilization	Diaphysis	n=0	n=1		
Radius/ Ulna	Primary fracture stabilization	Diaphysis	n=6	n=5	Screw pull-out; healing in mal-union (cat)	
					Non-union, screw in fracture gap (dog)	Screws replaced, osteostixis, cancellous bone graft
					Fracture through screw hole (cat)	With ALPS
		Metaphysis	n=1			
		Deux-étage-fracture Ulna	n=1			
	Revision surgery	Diaphysis	n=1			
Metacarpal bones	Primary fracture stabilization		n=1	n=1		
Femur	Primary fracture stabilization	Diaphysis	n=2	n=14		
		Metaphysis/ supracondylar		n=1	Screw pull-out, re-fracture (cat)	With other plate system
		Epiphysis (Salter Harris Type II)		n=1		
	Revision surgery	Diaphysis		n=1		
Tibia/ Fibula	Primary fracture stabilization	Diaphysis	n=2	n=2		
		Metaphysis		n=1		
Metatarsal bones	Primary fracture stabilization		n=1	n=1		
Pelvis	Primary fracture stabilization	Ilium	n=3	n=5		
		Acetabulum		n=1		
Sacrum	Primary fracture stabilization		n=1			
Mandible	Primary fracture stabilization		n=1			

Table 2: Overview of the 53 patients with bone fractures stabilized with ALPS.

Tarsal/carpal joint instability/luxation

ALPS was used to achieve 5 tarsal arthrodesis (2 partial and 3 panarthrodesis), 3 tarsal internal splints for dorsal instability (proximal intertarsal joint (n= 1), and tarsometatarsal joint (n = 2)) [17], and 4 cases of carpal panarthrodesis. Indication for arthrodesis was either instability or luxation of the carpal or tarsal joint. In two cases of tarsal panarthrodesis, ALPS was used for revision surgery: once to revise a re-fractured previous arthrodesis, and once to revise a failed collateral ligament repair. Tarsal partial arthrodesis were performed with plates positioned laterally in one case and medially and laterally in the other case. Pantarsal arthrodesis were performed in 3 cats with plates positioned dorsally in 1 case and medially in the other 2 cases. Carpal arthrodesis were performed with the plates positioned medially. In all the arthrodesis cases locking screws were used proximally and non-locking in the metabones. Data is provided in table 3.

Joint	Primary/ Revision surgery	Treatment	Dog	Cat	Complications	Revision after ALPS
Tarsal joint	Primary treatment	Partial Arthrodesis	n=2		Suture dehiscence (dog)	Plate removed
					Plate breakage (dog)	Plate removed
		Panarthrodesis		n=1	Suture dehiscence (cat)	Plate removed
		Internal Splinting		n=3		
	Revision surgery	Panarthrodesis		n=2	Suture dehiscence (cat)	Plate removed
					Suture dehiscence (cat)	Plate removed
Carpal joint	Primary treatment	Panarthrodesis	n=1	n=3	Not healing, loose implants (cat)	With ALPS

Table 3: Overview of the 12 patients with tarsal/carpal joint instability/luxation stabilized with ALPS.

In combination with total hip replacement (THR)

ALPS was used in combination with THR (Zurich Cementless®, Kyon Pharma, Inc., Zurich, Switzerland) in 6 dogs (THR = 6). In 4 dogs ALPS was applied in a preventive manner to buttress the proximal femoral region in dogs that were subjectively judged as having bad bone quality [18, 19], or when fissure lines were caused during surgery. In two cases ALPS was applied to stabilize fractures of the trochanter major during THR surgery. One fracture was stabilized with 2 ALPS (8 and 5). All the other cases were treated using a single plate (ALPS 8 n=1, ALPS 10 n=4). Data is provided in table 4.

Indication	Treatment with ALPS	Dog	Cat	Complications
Fracture of the trochanter major after THR	Fracture stabilization	n=2		
THR revision surgery	Prophylactic femoral buttressing	n=3		
THR, intraoperative fissure line	Prophylactic femoral buttressing	n=1		

Table 4: Overview of the 6 patients with THR additionally treated with ALPS.

Clinical outcome and complications

Fractures

50 of 54 fractures healed uneventfully. The following complications were found: The distal fixation of a plate positioned in the ulna in order to stabilize a comminuted proximal radius/ulna fracture of a 7 years old cat was applied too caudally and didn't get enough bone purchase. The screws pulled out through the caudal cortex resulting in caudal bowing of the ulna. It was only detected when healing was completed, and since the plate positioned in the radius maintained the fixation, no revision was performed. Complications that needed revision surgery were observed in 3 cases:

1) One month after the original surgery, a fracture occurred through the most proximal screw of a 7 holes ALPS 6,5mm used to stabilize a mid diaphyseal radius/ulna fracture in a 12 years old cat. During revision surgery, a longer ALPS 6,5mm plate bridging all the bone was positioned and healing occurred uneventfully.

2) A supracondylar femoral fracture in a cat was stabilized with an ALPS 8mm with 2 long locking screws in the distal fragment, and 3 locking monocortical screws positioned proximally. Twenty days after the surgery the proximal part of the fixation failed with all 3 monocortical screws being pulled out of the bone. During revision surgery 2 plates (one medially and one laterally) were positioned.

3) A closed comminuted proximal radius/ulna fracture in a 5 years old dog, stabilized with a ALPS 10 on the radius and ALPS 8 on the ulna, showed minimal signs of healing 10 weeks postoperative. At that time radiolucency around one

screw located in the fracture gap of the radius and around the proximal fixation of the ulna was detected. During revision surgery the loose screw in the radial fracture gap was removed and the proximal fixation of the ulna was reinforced. Osteostixis was performed and the fracture gap was filled with cancellous bone graft. A bacteriological sample taken during the revision revealed the presence of bacteria (Stapylococcus aureus). Five weeks after the revision surgery radiographic evidence of clinical healing was observed. Both plates were removed 2 years after the revision.

Tarsal/carpal joint instability/luxation

Of the 12 cases treated in this group the following complications were detected: Five months after a partial tarsal arthrodesis stabilizing a tarso-metatarsal instability in a dog, the laterally positioned plate broke at the level of the non-curetted proximal intertarsal joint. Since the arthrodesed joint was already bridged the plate was removed without further stabilization

The distal fixation of a pancarpal arthrodesis in a cat, become loose at 6 weeks after surgery. During revision surgery some remaining cartilage was removed, bone graft (vts, veterinary transplant services, inc., www.vtsonline.com, Kent, USA) was added and newly positioned screws replaced the non-locking screws of the distal fixation. Clinical union was observed 1 month after the revision.

The main complication in this group was suture dehiscence in the tarsal arthrodesis group (1 partial tarsal arthrodesis, 3 pantarsal arthrodesis). The cases were treated with bandages till radiographic evidence of bone healing was detected, and the plates have been removed. The skin healed in all 4 cases after implant removing without further complications.

In combination with total hip replacement (THR)

No complications with ALPS in combination with THR Zurich Cementless have been detected.

5 Discussion

The purpose of this retrospective study was to describe the newly developed ALPS system, to evaluate the first three years of its application at the Vetsuisse-Faculty of the University of Zurich and to describe the outcome of the patients. The ALPS system presents several particularities. Some of them appear to be advantageous. The possibility to contour the plates in both planes facilitates the placement on most of the bones. The specially designed in-plane bending pliers allow precise bending under the protecting of the screw-holes. The amount of bending is enough for most of the encountered situations. In cases like tarsal panarthrodesis with medially applied plates where more bending is needed, the correct joint angle could not be achieved with ALPS. The in-plane bending pliers didn't allow enough bending and using a standard bending plier would have resulted in deformation of the screw-holes. To compensate the incomplete bending in our two cases of tarsal panarthrodesis, the plates were positioned slightly cranial on the tarsus and the distal fixation of the plate started in the distal row of the tarsus. No complications related to this positioning were observed. Nevertheless, a specially curved plate to match the anatomical angle of the tarsus may be needed to provide a better apposition between bones and plate in future.

The combination of locking and non-locking screws was normally used for arthrodesis. It allowed to position larger locking screws proximally, and smaller non-locking screws in the metabones. The locking screws were considered to be too large to be safely positioned in the metabones without risking a fracture.

They were also too short to obtain enough bone purchase along all the metabones, and they could not be positioned in another angle than perpendicular to the plate. One out of 9 arthrodesis was revised with failure of this part of the fixation, although we believe that incomplete preparation of the articular surfaces was the cause. Again, specially dedicated plates with a proper angle, being thinner in the distal part and allowing the use of smaller locking screws in the distal part may be advantageous.

Suture dehiscence was a commonly encountered problem in tarsal arthrodesis with ALPS (4 out of 5 cases). The minimal soft tissue coverage in the tarsal region, open wounds associated with the tarsal joint injuries and previous surgeries in 2 of the cases may have contributed to this high rate of dehiscence. Still the thickness of the plate seems to be too excessive to support the tension created in the metatarsal area. Therefore the use of a tapered plate may be advantageous. High complication rates after tarsal arthrodesis have been previously reported [20-21], however in these publications suture dehiscence was not a common complication.

Monocortical screws are indicated in locking systems because the locking mechanism in the plate hole replaces the stabilization effect of the second cortex [3, 4, 7]. Before the placement of monocortical screws, the diameter of the bone needs to be assessed. In systems with a different thread diameter in the head of the screw, the screw tip will contact the trans cortex before locking the head in the plate if the bone diameter is smaller than the length of the screw shaft. This may lead to a damage of the bone threads in the near cortex making the screw to be prone for pullout [8, 9, 22]. In ALPS, where the screw-threads are always engaged in the thread of the plate-hole, contact with the trans cortex may lead to a fracture of it. In small patients with small diameter of the bone, bicortical screws may be used to reduce the risk of creating an iatrogenic fracture.

The locking screws of the ALPS must be positioned perpendicular to the plate and they have a larger diameter as compared to the screws of other systems. These facts make a good contouring of the plate mandatory in order to avoid misplacement of the screws or damaging more than one bone cortex as occurred in the previously described radius/ulna fracture in a cat. In this case the plate didn't get the needed contouring to match the procurvatum of the radius and therefore the most proximal screw hole of the plate couldn't be used. Additionally the screw positioned in the second screw hole damaged the cranial cortex of the radius resulting in a fracture one month later. The AO foundation recommends that the screws' diameter should not be larger than 40% of the entire bone diameter. ALPS screws sometimes reach or even exceed this limit which enhances the risk of fractures through the screw-hole. Nevertheless, thicker screw cores provide better bone purchase and increase bending stiffness [3]. Still care in the positioning is mandatory to avoid this type of complications. The use of monocortical screws may be beneficial to avoid excessive debilitation of the bone.

If self-tapping screws are used, the cutting flutes must extend beyond the bone cortex. Otherwise not enough purchase will be obtained which leads to a potential collapse of the fixation [23] as occurred in one of our cases. In that case

three short monocortical screws were used to stabilize the proximal aspect of the plate. This is particularly important when using monocortical screws because they only have 60% of the pullout strength of a standard bicortical screw [7].
In the human field the use of monocortical screws is recommended only in diaphyseal areas with good bone quality [8]. In most of our cases we used monocortical screws in diaphyseal bone. Longer non-locking mono-or bicortical screws were used when approaching the metaphysis as the longest locking screw available in ALPS is only 20 mm long and it does not reach the trans cortex in wider metaphyseal areas. In cases where angulation of the screw was needed, bicortical non-locking screws were used. Still, the use of monocortical locking screws is recommended to preserve endosteal blood supply and thereby enhancing bone healing [1, 7]. This also allows to have the self-tapping part of the screw being protected in the endosteal cavity and eliminates the need to measure for the length of the screw when using MIPO techniques [4, 8, 22].
The limited plate to bone contact of the ALPS prevents damage to the periosteal blood perfusion and reduces necrosis under the plate [3, 7]. As a consequence the risk of infection is decreased and fracture healing accelerates [1]. It may also reduce the risk of screw loosening due to bone necrosis under the plate when using monocortical screws.
The presence of bacteria was found in one case of a comminuted radius/ulna fracture, which didn’t heal properly. In that case, one of the locking screws was positioned in the fracture gap, and all other 9 plate-holes were filled with screws. We suspect that stress concentration in the gap associated with the presence of

a relatively large screw, and the extensive preparation performed for application of the implants, affected healing and made conditions favorable for bacterial colonization. Removal of the loose screw, positioning of bone graft and osteostixis were enough to achieve bone healing after revision. We also suspect that the better biocompatibility of titanium as compared to stainless steel [24] and the reduced contact between implant and bone, may have contributed to the fast bone healing (5 weeks), after removal of the loose screw.

The engagement of threads between the screws and plate-holes causes loss of surgical feeling during insertion of screws. As the screws will be tightened even when not positioned in the bone, the surgeon may miss that the screw is misplaced. This is a reported problem in human and in veterinary surgery [4, 7, 9, 22]. In biological osteosynthesis techniques this represents the bigger issue as reduced approaches are used. Proper positioning of the drilling guide, and proper feeling of the drill bit passing the cortical bone may help to reduce this potential problem.

As opposed to conventional locking plates where different threads are used between screw head and shaft, ALPS screws have only one thread. Therefore using ALPS bone-plate contact is needed at least when the first 2 screws are positioned. Without bone-plate contact the reduction is lost during tightening of the screws. Using locking plate systems with independent threads in the head and the shaft of the screw, no bone-plate contact is needed. This makes plate positioning easier [2, 8, 9].

ALPS also allows for axial compression. This is a potential advantage being less often used, since more biological techniques are applied [3]. Still in special cases, like in arthrodesis, it was used to increase stability.

We found difficulties inserting and removing larger sizes of screws. ALPS drill guides are not threaded and locked into the plate as sleeves of other locking systems are [2, 25]. Therefore the guides need to be held in position during drilling manually and if the guide is not perfectly centered and perpendicular to the plate, the screw will be also positioned eccentrically making its insertion or removal more difficult. To counteract this issue Kyon developed locking threaded guides for the non-locking systems of ALPS 6 and 8, and is planning to do the same for all the sets. This is not ideal but at least a well-centered pilot hole can be drilled in this manner. In 2010 (after completion of this study), and to facilitate screw insertion/removal, the cutting flutes and the screw thread were improved.

Based in the results of this study, we can conclude that ALPS is a suitable option to treat fractures and some other orthopedic conditions in small animals, with reasonable handling possibilities. Improvements in the drilling guide design may facilitate its use. Further investigation is needed to evaluate the effect of implant design and material in infection rates and healing times.

6 References

1. Boudrieau, R.J. *Advanced Locking Plate System (ALPS): rationale, biomechanics and early clinical use*. in *WVOC* 2010. Bologna (Italy),.

2. Schwandt, C.S. and P.M. Montavon, *Locking compression plate fixation of radial and tibial fractures in a young dog.* Vet Comp Orthop Traumatol, 2005. **18**(3): p. 194-8.

3. Perren, S.M., *Evolution of the internal fixation of long bone fractures. The scientific basis of biological internal fixation: choosing a new balance between stability and biology.* J Bone Joint Surg Br, 2002. **84**(8): p. 1093-110.

4. Eijer, H., et al., *PC-Fix and local infection resistance--influence of implant design on postoperative infection development, clinical and experimental results.* Injury, 2001. **32 Suppl 2**: p. B38-43.

5. Tepic, S., et al., *Strength recovery in fractured sheep tibia treated with a plate or an internal fixator: an experimental study with a two-year follow-up.* J Orthop Trauma, 1997. **11**(1): p. 14-23.

6. Sikes, J.W., Jr., et al., *Comparison of fixation strengths of locking head and conventional screws, in fracture and reconstruction models.* J Oral Maxillofac Surg, 1998. **56**(4): p. 468-73.

7. Haidukewych, G.J., *Innovations in locking plate technology.* J Am Acad Orthop Surg, 2004. **12**(4): p. 205-12.

8. Miller, D.L. and T. Goswami, *A review of locking compression plate biomechanics and their advantages as internal fixators in fracture healing.* Clin Biomech (Bristol, Avon), 2007. **22**(10): p. 1049-62.

9. Voss, K., et al., *Repair of long-bone fractures in cats and small dogs with the Unilock mandible locking plate system.* Vet Comp Orthop Traumatol, 2009. **22**(5): p. 398-405.

10. Perren, S.M., *Backgrounds of the technology of internal fixators.* Injury, 2003. **34 Suppl 2**: p. B1-3.

11. Schmokel, H.G., et al., *Treatment of tibial fractures with plates using minimally invasive percutaneous osteosynthesis in dogs and cats.* J Small Anim Pract, 2007. **48**(3): p. 157-60.

12. Hudson, C.C., A. Pozzi, and D.D. Lewis, *Minimally invasive plate osteosynthesis: applications and techniques in dogs and cats.* Vet Comp Orthop Traumatol, 2009. **22**(3): p. 175-82.

13. Guiot, L.P. and L.M. Dejardin, *Prospective evaluation of minimally invasive plate osteosynthesis in 36 nonarticular tibial fractures in dogs and cats.* Vet Surg, 2011. **40**(2): p. 171-82.

14. Inauen, R., D. Koch, and M. Bass, *Arthrodesis of the tarsometatarsal joints in a cat with a two hole advanced locking plate system.* Vet Comp Orthop Traumatol, 2009. **22**(2): p. 166-9.

15. Blake, C.A., et al., *Single cycle to failure in bending of three standard and five locking plates and plate constructs.* Vet Comp Orthop Traumatol. **24**(6): p. 408-17.

16. Cabassu, J.B., et al., *Single cycle to failure in torsion of three standard and five locking plate constructs.* Vet Comp Orthop Traumatol. **24**(6): p. 418-25.

17. Voss, K., M. Keller, and P.M. Montavon, *Internal splinting of dorsal intertarsal and tarsometatarsal instabilities in dogs and cats with the ComPact Unilock 2.0/2.4 (TM) system.* Veterinary and Comparative Orthopaedics and Traumatology, 2004. **17**(3): p. 125-130.

18. Andreoni, A.A., et al., *Revision of an unstable HELICA endoprosthesis with a Zurich cementless total hip replacement.* Vet Comp Orthop Traumatol, 2010. **23**(3): p. 177-81.

19. Guerrero, T.G. and P.M. Montavon, *Zurich cementless total hip replacement: retrospective evaluation of 2nd generation implants in 60 dogs.* Vet Surg, 2009. **38**(1): p. 70-80.

20. Roch, S.P., et al., *Complications following tarsal arthrodesis using bone plate fixation in dogs.* J Small Anim Pract, 2008. **49**(3): p. 117-26.

21. McKee, W.M., et al., *Pantarsal arthrodesis with a customised medial or lateral bone plate in 13 dogs.* Vet Rec, 2004. **154**(6): p. 165-70.

22. Gautier, E. and C. Sommer, *Guidelines for the clinical application of the LCP.* Injury, 2003. **34 Suppl 2**: p. B63-76.

23. Murphy, T.P., et al., *Pullout properties of 3.5-mm AO/ASIF self-tapping and cortex screws in a uniform synthetic material and in canine bone.* Vet Surg, 2001. **30**(3): p. 253-60.

24. Arens, S., et al., *Influence of materials for fixation implants on local infection. An experimental study of steel versus titanium DCP in rabbits.* J Bone Joint Surg Br, 1996. **78**(4): p. 647-51.

25. Keller, M.A., K. Voss, and P.M. Montavon, *The ComPact UniLock 2.0/2.4 system and its clinical application in small animal orthopedics.* Vet Comp Orthop Traumatol, 2005. **18**(2): p. 83-93.

7 Cases

Case 1

Abbildung 1

Craniocaudal and mediolateral radiographs of a 12 years old cat showing tarsometatarsal dorsal instability

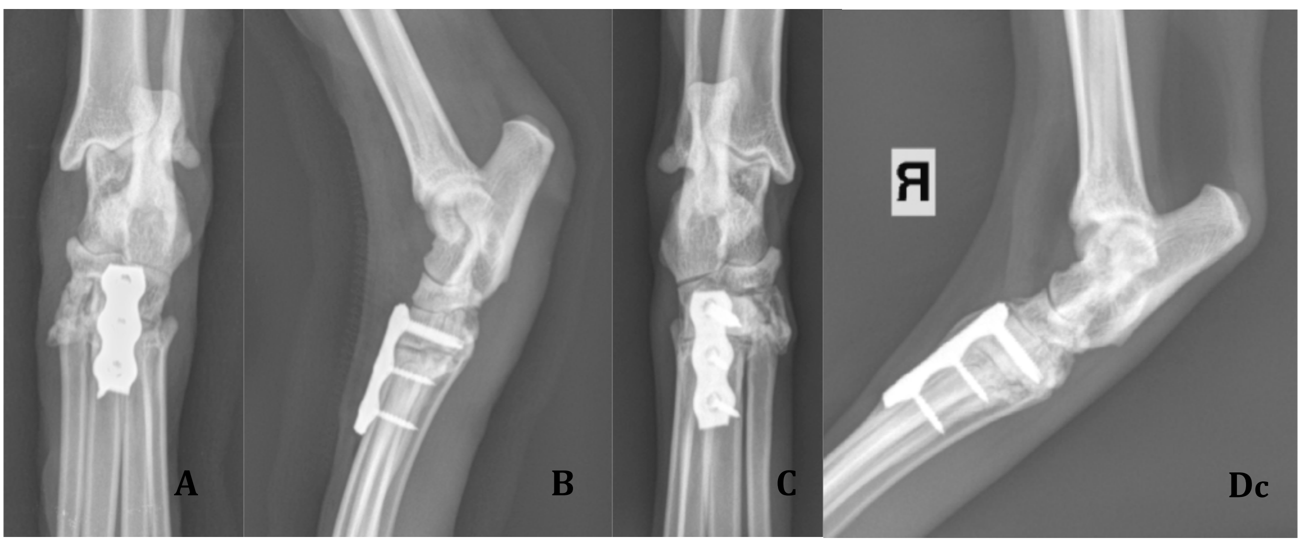


Abbildung 2

Immediate postoperative (A, B) and 8 months postoperative (C, D) craniocaudal and mediolateral radiographs. The tarsometatarsal instability was internally splinted with a dorsally applied ALPS 5, bridging the tarsometatarsal joint, using one locking screw and two non-locking screws

Case 2

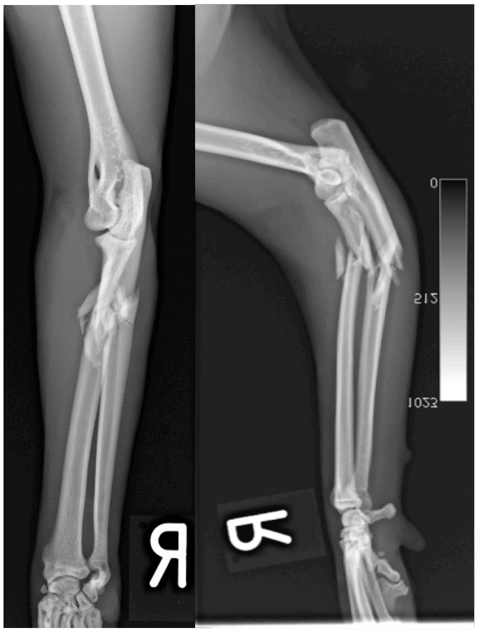


Abbildung 3

Craniocaudal and mediolateral radiographs of a 7 years old cat showing a proximal diaphyseal comminuted radius/ulna fracture

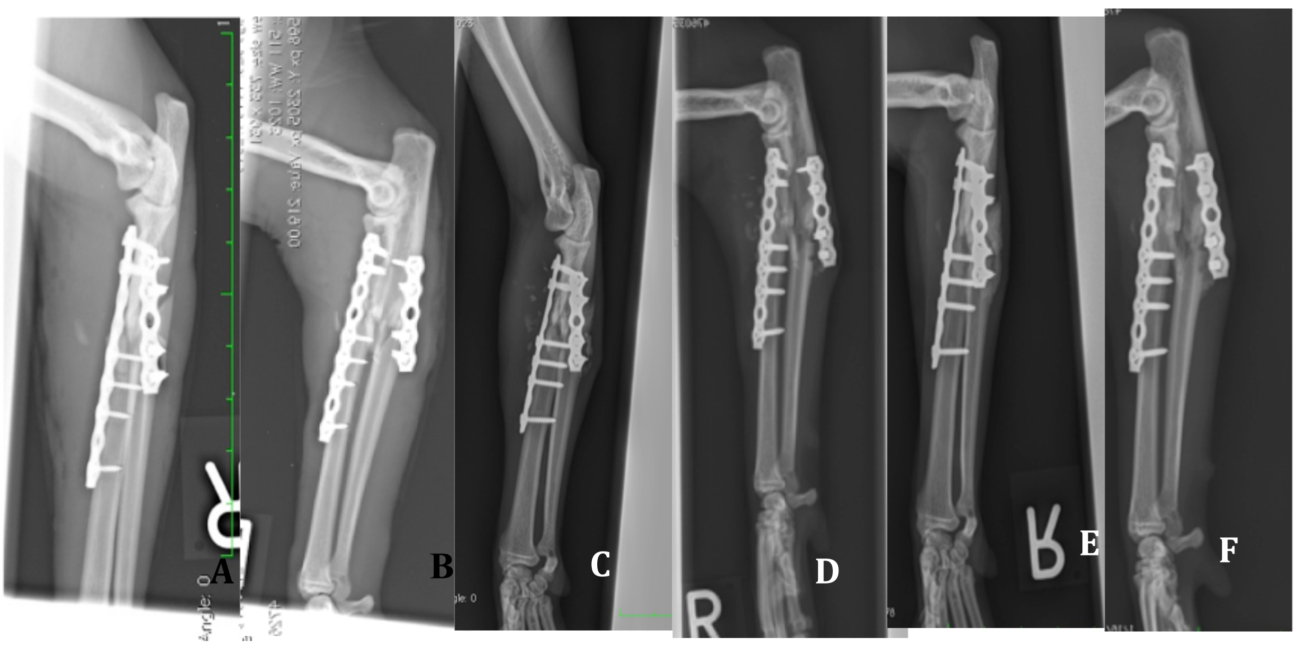
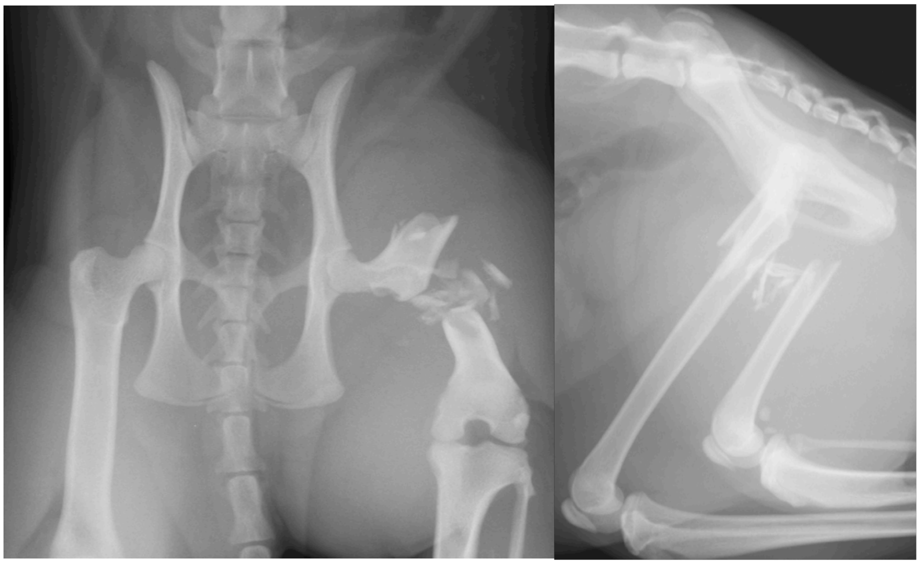


Abbildung 4

Immediate postoperative (A, B), 6 weeks (C, D) and 11 weeks (E, F) postoperative craniocaudal and mediolateral radiographs. The ulna was plated with a short ALPS 5 and the radius with a longer ALPS 5, both plates with locking- and non-locking screws. The monocortical screws in the distal ulna fragment were positioned too caudally and do not have good bone purchase (A, B), resulting in screw pull-out (C, D). No revision took place and the ulna healed in a mal-union position (E, F)

Case 3



Craniocaudal and laterolateral radiographs of a one year old cat showing a proximal diaphyseal comminuted femoral fracture

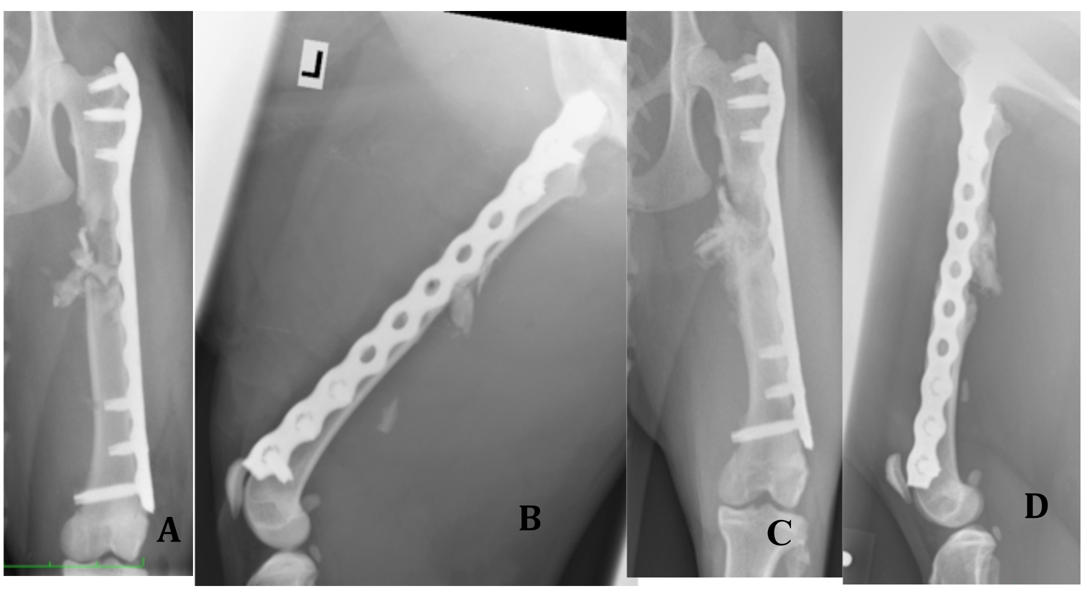


Abbildung 6

Immediate postoperative (A, B) and 6 weeks (C, D) postoperative craniocaudal and mediolateral radiographs. The femur was plated with a ALPS 8 with three locking screws per fragment. Long screws were used in metaphyseal areas, and short monocortical were positioned in diaphyseal bone

Case 4

Abbildung 7

Lateral radiographs in extended and neutral position of the carpal joint of a one year old cat showing a fracture of the accessory carpal bone with rupture of the palmar ligaments

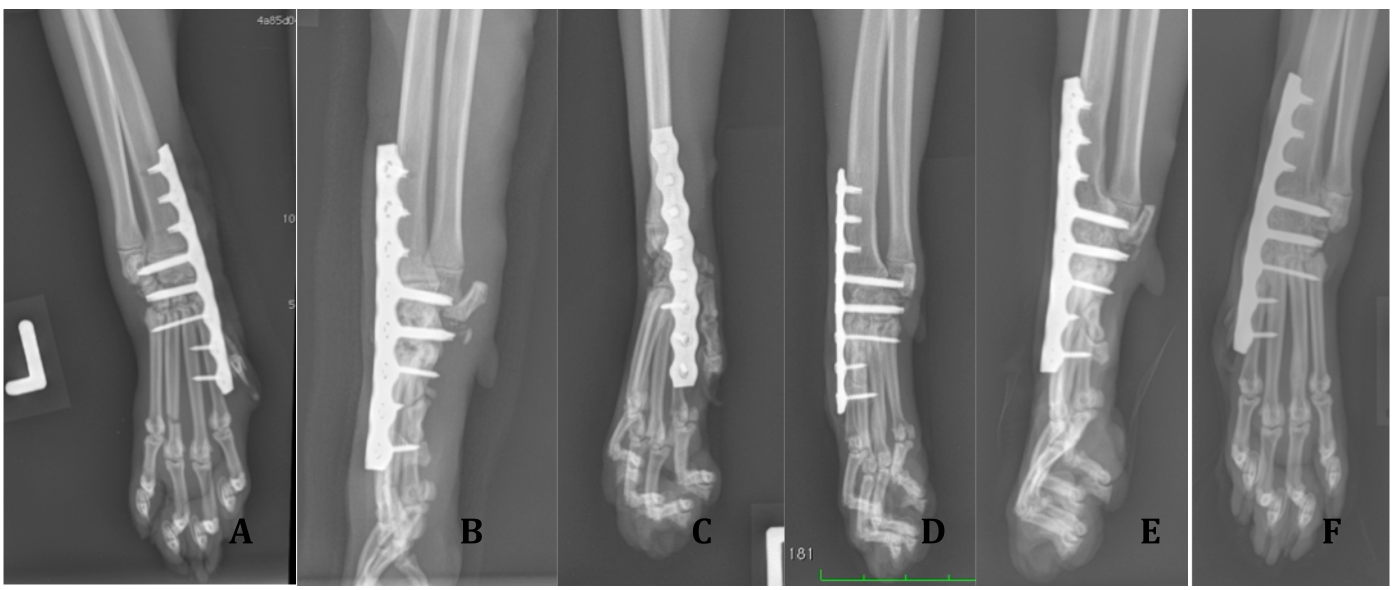


Abbildung 8

Immediate postoperative (A, B) , 6 weeks (C, D) and 13 weeks (E, F) postoperative craniocaudal and mediolateral radiographs. A pancarpal arthrodesis with a ALPS 6,5 from the medial side was performed, using locking screws in the radius and carpal joint, and non-locking screws in the metacarpal bones

Case 5

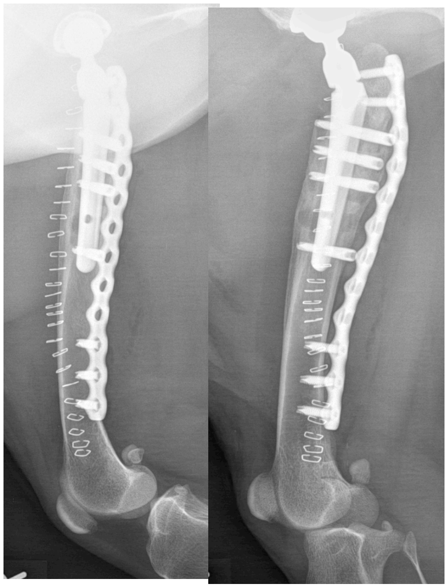


Abbildung 9

Immediate postoperative mediolateral and oblique radiograph showing prophylactic femoral stabilization during revision surgery of total hip replacement (stem replaced because of implant loosening)

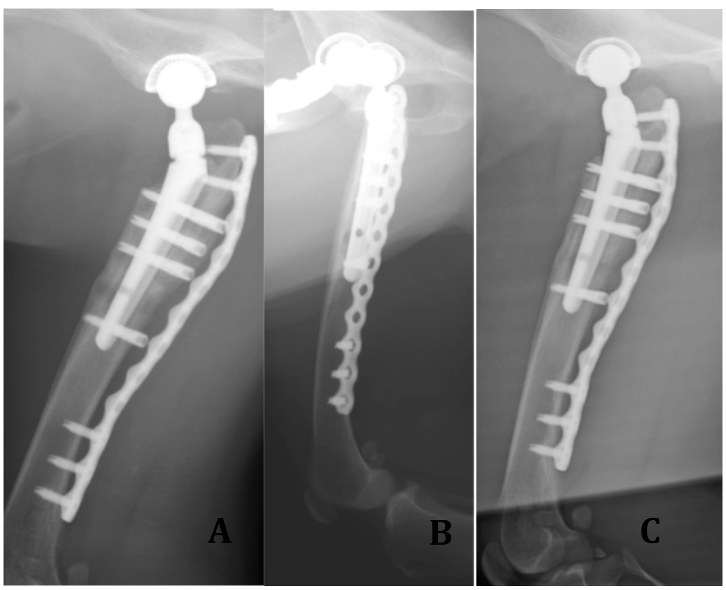


Abbildung 10

6 weeks (A, B) and 6 months (C) postoperative mediolateral radiographs after revision of THR. The femur was plated with a ALPS 10 from the lateral side, using only monocortical screws

Lebenslauf

Name	Nicole Scherrer
Geburtsdatum	11.02.1984
Geburtsort	Zürich
Nationalität	Schweiz
Heimatort	Zürich
1990 – 1999	Grundschule, Langnau am Albis, Schweiz
2000 – 2003	Mathematisch-naturwissenschaftliches Gymnasium Rämibühl, Zürich, Schweiz
2003	Abschluss: Matura
09/ 2003 – 10/ 2009	Studium der Veterinärmedizin, Vetsuisse-Fakultät Zürich, Schweiz
10/ 2009	Staatsexamen, Vetsuisse-Fakultät Zürich, Schweiz
06/ 2010 – 06/ 2013	Anfertigung der Dissertation unter Leitung von Prof. Dr. med. vet. Patrick R. Kircher, Direktor des Departements für Kleintiere, Leiter der Abteilung für Bildgebende Diagnostik und ad interims Direktor der Klinik für Kleintierchirurgie der Vetsuisse-Fakultät Universität Zürich, Schweiz
11/ 2009 – 11/ 2010	Assistentenstelle Kleintierchirurgie, Tierspital Zürich, Schweiz
04/ 2011 – 04/ 2012	Internship Kleintierchirurgie, Tierspital Zürich, Schweiz
07/ 2012 – 12/ 2012	Assistentenstelle Kleintierchirurgie, Tierspital Zürich, Schweiz

August 2013, Zürich

Danksagung

Besonders bedanken möchte ich mich beim Korreferenten Prof. Dr. med. vet. Tomás Guerrero für die Überlassung des Themas sowie die ausgezeichnete und aufwändige fachliche Betreuung.

Ein grosses Dankeschön geht auch an den Referenten Prof. Dr. med. vet. Patrick R. Kircher für die sehr angenehme Zusammenarbeit und exzellente Betreuung.

Ausserdem danke ich dem Team der Radiologie und Kleintierchirurgie, welche mir jederzeit bei Fragen und Problemen unterstützend zur Seite gestanden haben.

Meinen Eltern und Brüdern, meinem Freund und meinen Freunden danke ich für die herzliche und aufmunternde Unterstützung während der Bearbeitung meiner Doktorarbeit.